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FIELD-OF-VIEW ASSESSMENT OF LOW-LEVEL FLIGHT AND AN AIRDROP IN THE C-130 WEAPON SYSTEM TRAINER (WST)

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13. ABSTRACT *(Maximum 200 words)*
In order to provide a cost-effective simulator training environment, a number of variables must be optimized to meet training requirements with minimum cost. One such variable is the field of view (FOV) of the visual display. The present investigation examined the effect of FOV on pilot performance for low-level flight and an airdrop in the C-130 Weapon System Trainer (WST). The study was performed using two different FOV configurations. The full-FOV condition used all six windows to provide a 160°H by 35°V visual field. The limited-FOV condition used only the forward four windows to provide a 102°H by 35°V visual field from the left seat (pilot's). The tasks chosen by subject-matter experts for the study were thought to be those most likely to require information from the peripheral windows. Automated pilot performance measures and eye position data were collected throughout the study. Twelve experienced C-130 pilots performed four trials over two different routes under both FOV conditions. The pilot performance data showed no strong or consistent effects due to the FOV manipulation. The eye position data revealed an increased use of the front window and instruments in the limited-FOV condition and a decreased use of the window to the left of the pilot. Results show that the peripheral windows may not be required for experienced pilots, but that if the windows are turned on, pilots use a different visual strategy. Based on the results of the study, a

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preliminary conclusion would be to provide a full FOV when the training objectives include tasks that require a large amount of peripheral information. Before any final conclusions can be reached regarding FOV requirements, however, the use of the windows from the copilot's position should be addressed, as well as the value of the peripheral windows for skill acquisition by less experienced pilots.

SUMMARY

The purpose of this effort was to determine the requirement for the far peripheral windows and associated imagery for low-level navigation and airdrop tasks. Although these windows are available for use by the pilot and copilot, their inclusion was primarily for the navigator position. Currently, the navigator position is not included in the simulator training syllabus. If the imagery currently provided in the peripheral windows could be allocated to the remaining scene, the level of detail in the scene could be considerably enhanced. Previous research has shown that the enhanced scene content resulted in superior pilot performance.

A within subjects design was used in which 12 experienced C-130 pilots performed four trials over two different routes under two field-of-view (FOV) conditions. Automated pilot performance measures and eye position data were collected. The pilot performance data showed no strong or consistent effects as a result of the FOV manipulations. However, the eye position data revealed an increased use of the front window and instruments, and a decreased use of the window to the left of the pilot in the limited-FOV condition. The conclusions of the study are that the peripheral windows may not be required for experienced pilots, but that their presence or absence results in different visual behaviors. It is recommended that a full FOV be provided when the training objectives include tasks that require a large amount of peripheral information. Keywords: aircraft windows; navigation; human performance, [illegible]

PREFACE

The present investigation was conducted by the Operations Training Division of the Air Force Human Resources Laboratory (AFHRL) in support of AFHRL's Technical Planning Objective (TPO) entitled Visual Scene Requirements. The goal of this TPO is to develop guidelines for visual system designers and users.

The current investigation was conducted under Work Unit 1123-32-04, Simulator Field-of-View Requirements. The goal of this effort was to determine if changing the field of view would affect performance of low-level flight and an airdrop in the C-130 Weapon System Trainer (WST). The results of this effort will be used to validate the C-130 WST and to provide recommendations for the future C-17 WST.

The authors wish to thank the members of the 34th Tactical Training Group SIMCERT, Little Rock AFB, Arkansas, for providing technical assistance and serving as subjects.

The authors would also like to thank Ms. Eileen M. Evans for her time and effort in helping to prepare this report.

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FIELD-OF-VIEW ASSESSMENT OF LOW-LEVEL FLIGHT AND AN AIRDROP IN THE C-130 WEAPON SYSTEM TRAINER (WST)

I. INTRODUCTION

The field of view (FOV) provided by the visual system is an important determinant of the number and types of tasks that can be trained in the simulator. The visual FOV influences the interaction among vision, apparent motion perception, and vehicle control. Factors affected by FOV are perceptions of depth, altitude, and apparent motion. Pilot control strategy may also be impacted by the size and placement of the FOV. Additionally, there is a trade-off between the level of scene detail, resolution, and FOV size. The high-fidelity solution is to provide the same visual area as that available in the aircraft; however, this approach may be impractical for operational simulators due to the cost for full-FOV systems. The size of the visual display needs to be related to training objectives and demonstrated effectiveness.

The traditional approaches for determining the desired or required FOV for simulators use either questionnaires or performance data. The questionnaire approach evaluates pilot opinion concerning specific FOVs. Although this type of data collection is widely used, it suffers from being subjective in nature, and gives no indication of the portion of the FOV being used or where attention is allocated. The pilot performance approach uses measures taken from the simulator as the pilot performs a mission. The measures are either compared to those for other FOV configurations or compared against a criterion. If two alternatives are not found to differ, the less expensive one is recommended. However, performance measures do not take into account the fact that different strategies might be used by the pilots yet result in equivalent performance levels.

II. BACKGROUND

Collyer, Ricard, Anderson, Westra, and Perry (1980), in a summary of research relating to FOV requirements for straight-in landings and takeoffs, found that safe and acceptable straight-in landings and takeoffs could be performed in FOV configurations with dimensions of 10°H (horizontal) by 10°V (vertical), 21.5°H by 21.5°V, and 5.7°H by 37°V. The pilots' performance was rated by pilots positioned outside the simulator, and FOV determinations of safe and acceptable were based on raters' recommendations. The most important finding in this series of studies was that acceptable performance was obtained with FOV configurations that were significantly smaller than those commonly being used in simulation.

FOV requirements for other contact maneuvers have also been investigated. Three studies performed from 1977 to 1979 used FOV as a research variable, in conjunction with other environmental factors (Irish & Buckland, 1978; Irish, Grunzke, Gray, & Waters, 1977; Nataupsky, Wagg, Weyer, McFadden, & McDowell, 1979). Undergraduate pilot students performed aileron rolls, barrel rolls, and the 360-degree overhead pattern. Using various FOVs, these studies showed that the effect of the FOV variable was extremely task-specific for the investigated maneuvers, but that generally performance improved as the FOV increased. There is considerable interest in the FOV requirements for operational mission training including tasks such as low-level flight, aerial refueling, air-to-air, and air-to-ground maneuvers. The present investigation examined the effects of FOV manipulations on mission-related tasks for the C-130.

Statement of the Problem

The primary mission of the C-130 is the movement of cargo and personnel from one location to another. This is done in a variety of environmental conditions, combat areas, airfields, and

III. METHOD

Subjects

Twelve male C-130 pilots with a crew qualification of instructor pilot or aircraft commander served as subjects for this study. On the average, subjects had 1,740 hours in the C-130 and 2,549 hours of total flying time.

Apparatus

The study was conducted on the C-130 WST located at Little Rock AFB, Arkansas. The C-130 WST is a full-mission simulator which provides computer-generated imagery for out-of-the-window visual cues. The visual system produces day, dusk, and night scenes through a six-window, five-channel, color CRT display system with infinity optics. The image generator is capable of generating 8,000 visible edges and 4,000 point lights simultaneously. Other system features include textured surfaces, seven simultaneous moving models (aircraft, missiles, or land vehicles), threats, and instructor-controlled weather effects.

The six windows in the display can be turned on or off independently to provide various configurations for research purposes (see Figure 1). The main focus of the present effort was the effect of the peripheral cues on flight performance. This study used two FOV configurations to examine the effects of FOV on task performance. The full-FOV condition (all windows on) provided the pilot with a 160^{o}H by 35^{o}V FOV, and the limited-FOV condition (Windows 3 and 6 turned off) provided a 102^{o}H by 35^{o}V FOV from the pilot's head position (see Figure 2).

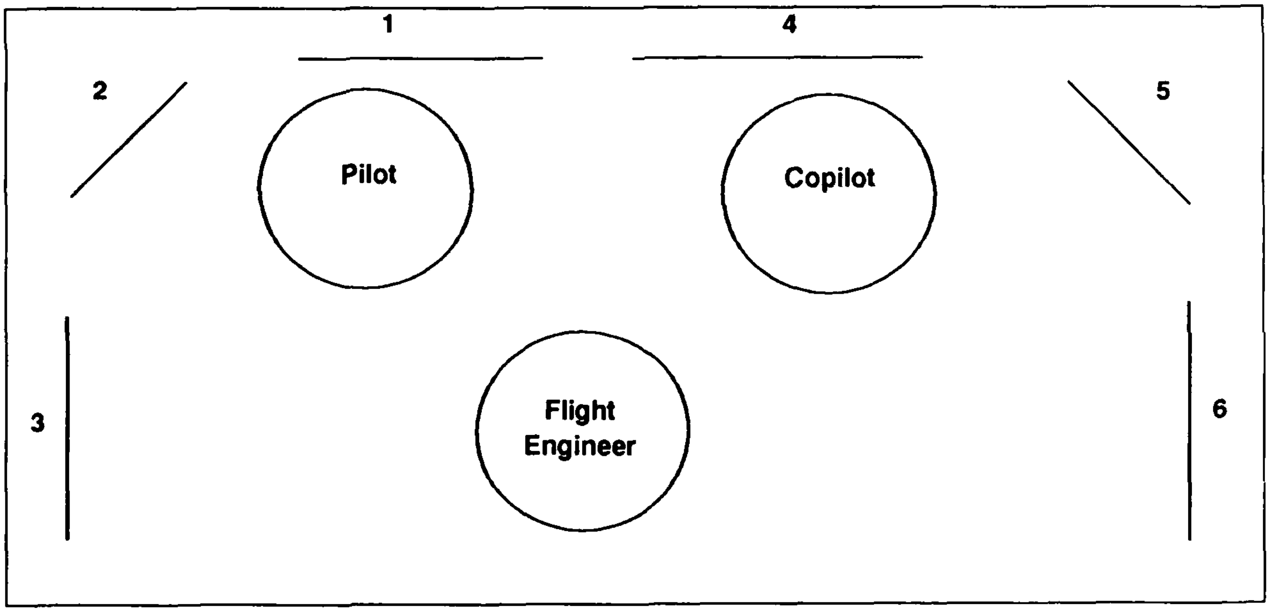

Figure 1. **C-130 WST Window Configuration.**

Performance Measurement

Objective data were collected at a continuous 10-Hertz update rate from the visual interface of the simulator. The performance measures included pilot control inputs and system parameters (see list in Experimental Design Section). A second set of data was collected from an eye

tracking monitor/camera. The eye movement device used photoelectric sensing and processing techniques to determine focal point, magnitude and direction of eye movements (see Appendix A for System Specifications). This device allows free head movement. The visual scene and focal points were recorded on videotape and time-coded to a .01-second accuracy. Figures 3, 4, 5, and 6 provide examples of the data collection system and the eye focal point scenes.

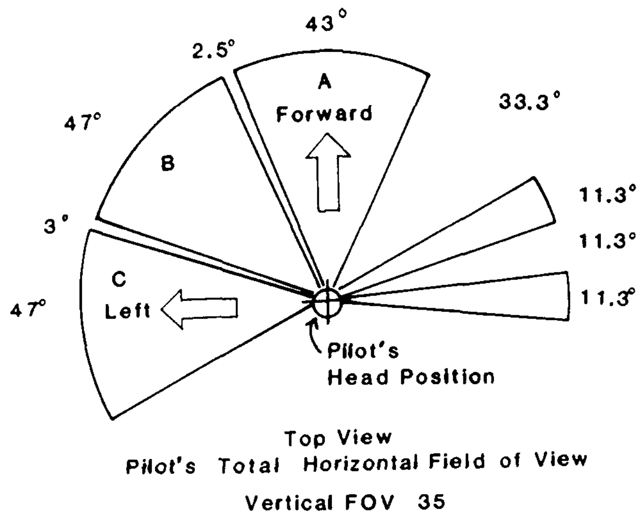

Figure 2. **C-130 WST Pilot's Field of View.**

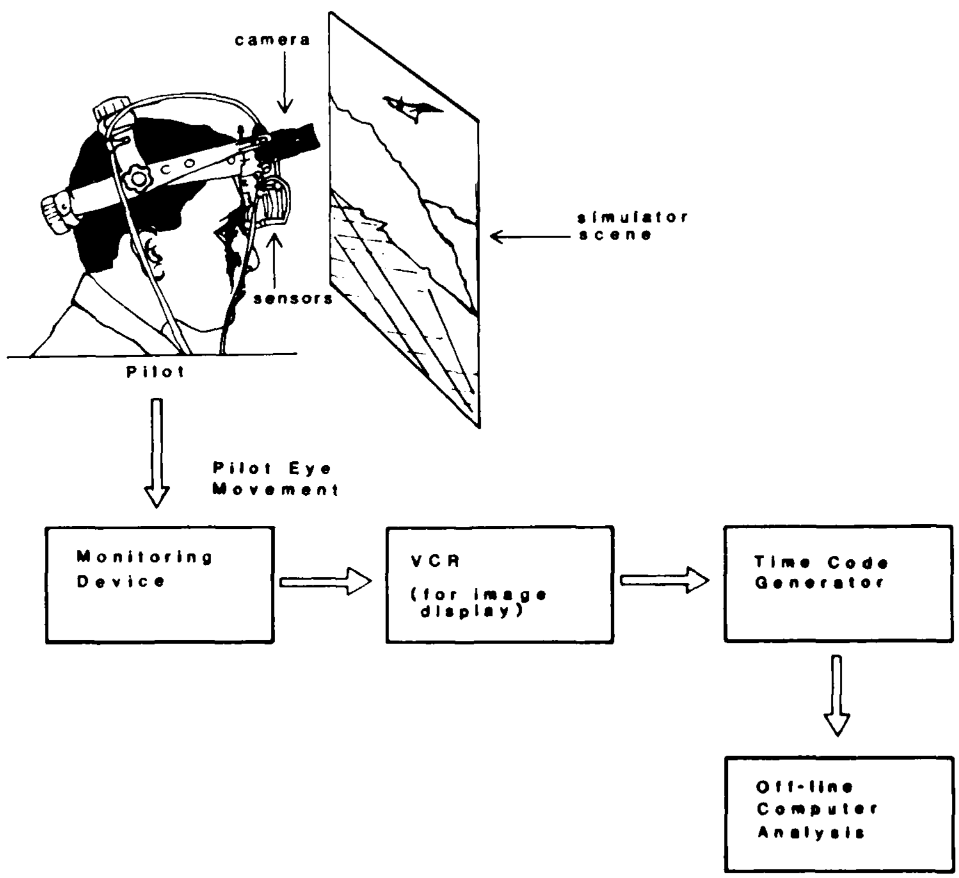

Figure 3. **Diagram of Eye Tracking System.**

Task Description

The basic task was low-level navigation to a drop and escape. The ingress section consisted of two legs, each requiring heading changes. The third leg consisted of a drop, followed by a short egress segment. Two similar mission routes were designed for the study. Each route included two low-level portions, followed by an airdrop segment. The terrain of both routes was slightly mountainous over wooded areas (Ozark National Forest). The routes were essentially equivalent in design and terrain. For Route 1 (see Figure 7), the aircraft was positioned at a predetermined point (Road Bend) at 300 feet above ground level (AGL). The pilot was instructed to maintain an airspeed of 210 knots, an altitude of 300 feet AGL, and a heading of 103 degrees. After approximately 7.2 miles (Road Bend), a heading change was made to 047 degrees for 4.3 miles (River Y), followed by a heading change to 029 degrees for 1.2 miles. At this point (Highway 7), the pilot performed a slowdown maneuver (400 feet AGL, 130 knots) to position the aircraft for the airdrop. After locating the drop zone and configuring the aircraft for the drop (flaps lowered, pre-drop checklist completed), the pilot increased airspeed and altitude for a short escape segment.

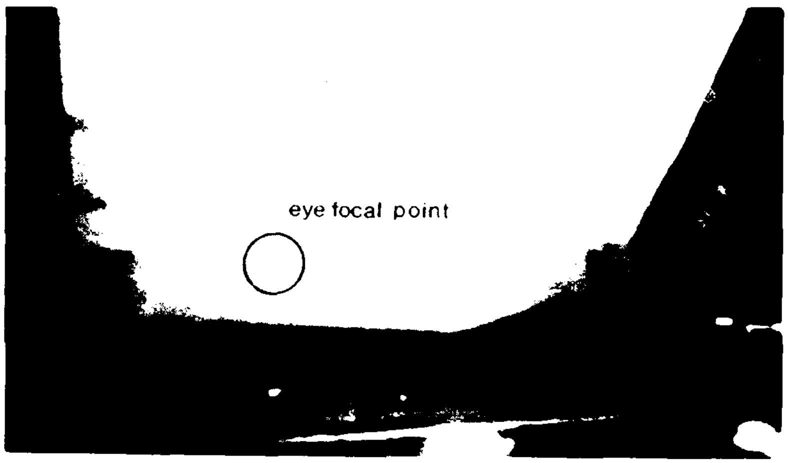

Figure 4. **Pilot's Eye Position in Simulator Front Window.**

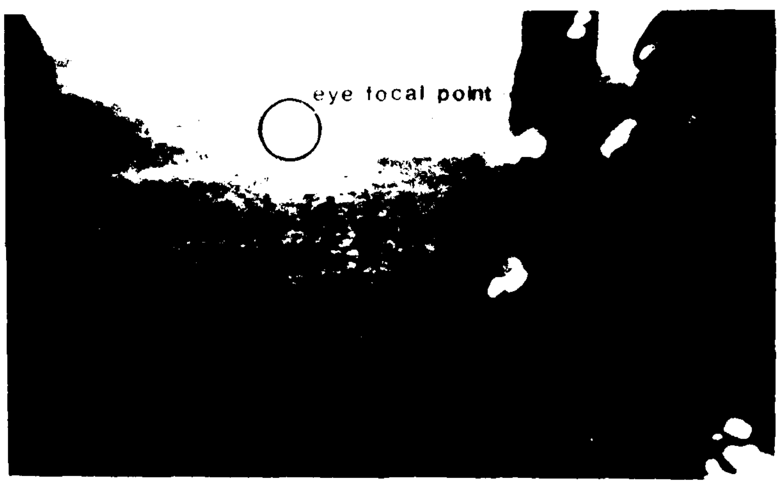

Figure 5. **Pilot's Eye Position in Simulator Side Window.**

Route 2 (see Figure 8) used the same altitudes, airspeeds and drop zone. The initial point was located at a lock and dam at 300 feet AGL and 210 knots. The pilot flew 0.7 mile at a heading of 262 degrees to a road intersection. A heading change to 295 degrees for 8.7 miles

positioned the pilot at a road bridge for the final segment. After assuming a heading of 260 degrees for 0.7 mile, the pilot executed a slowdown maneuver for the airdrop. After the airdrop, a short escape ended the route.

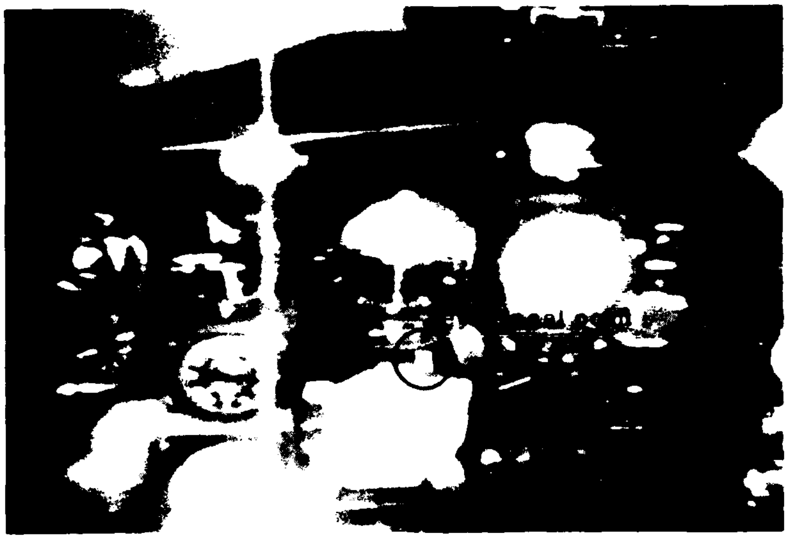

Figure 6 **Pilot's Eye Position in Simulator Instrument Panel.**

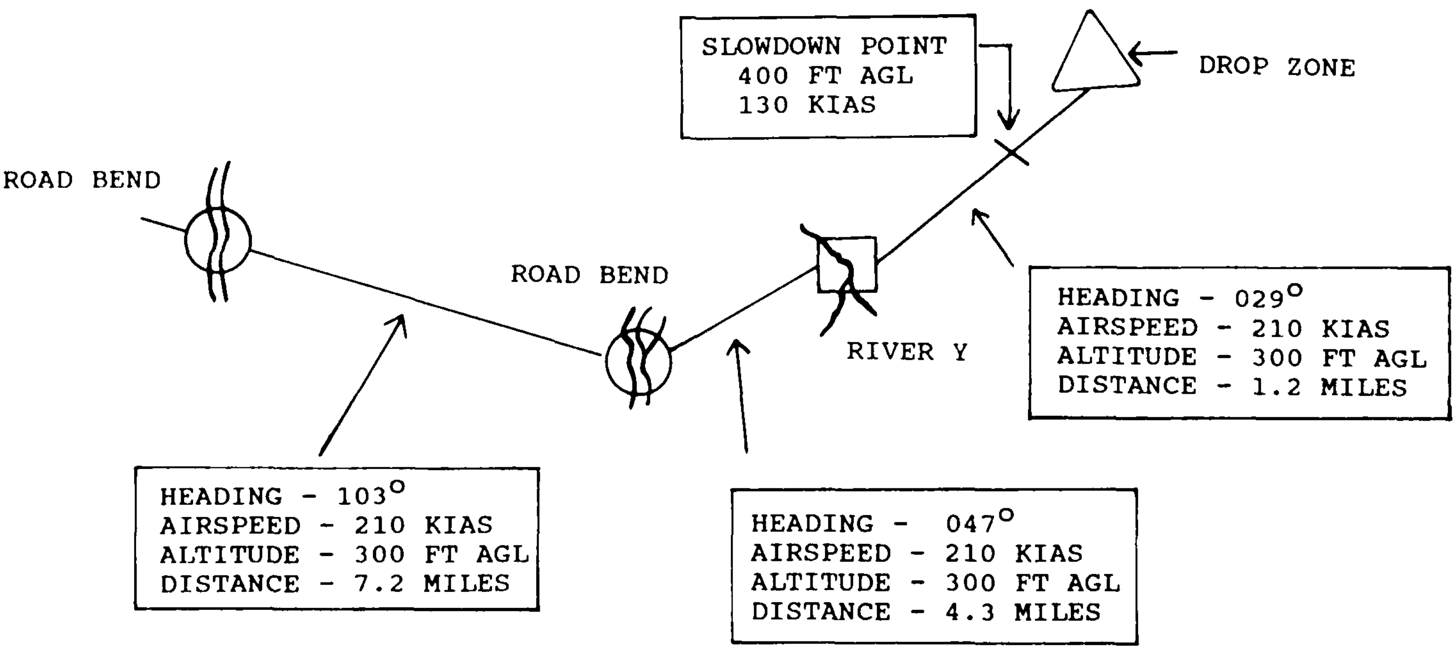

Figure 7. **Flight Profile for Route 1.**

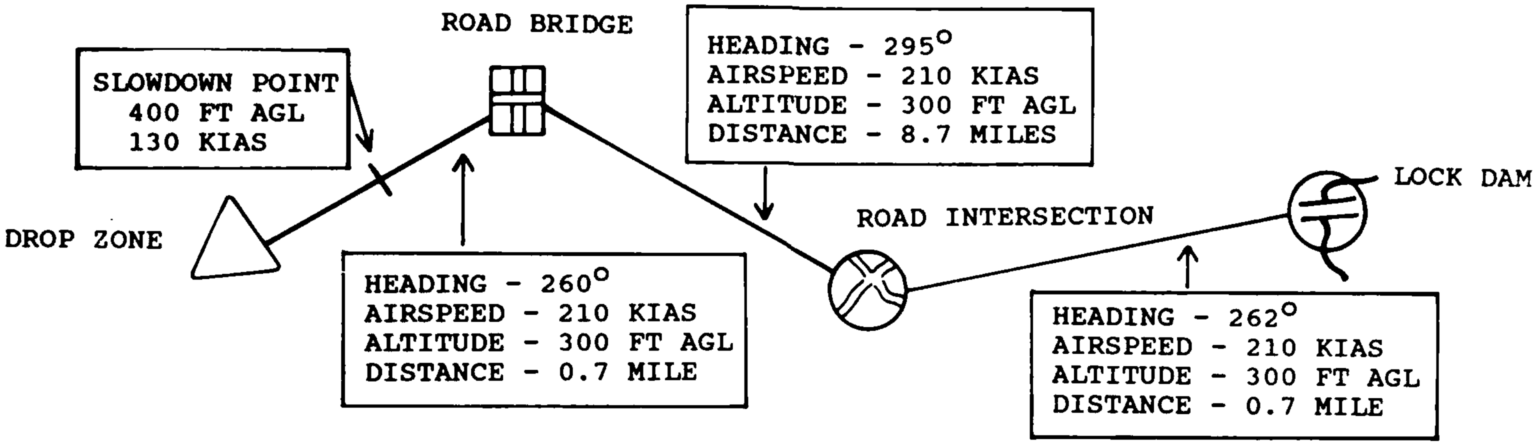

Figure 8. **Flight Profile for Route 2.**

Experimental Design

The present investigation used a randomized block design, with all experimental factors repeated within subjects. Order effects were controlled through counterbalancing.

The independent variables were FOV (full vs. limited) and route (Route 1 or Route 2).

The variables available for analysis included both the simulator objective performance measures and eye position data. The performance measures collected were as follows:

Knots Indicated Airspeed (KIAS)	Angle of Attack (Degrees)
Sideslip (Degrees)	Normal Acceleration (Gs)
Bank Angle (Degrees)	Pitch Angle (Degrees)
Pedal Position	Wheel Position
Stick Position	Yaw Rate (Degrees per Second)
Roll Rate (Degrees per Second)	Pitch Rate (Degrees per Second)
X-axis Acceleration	Y-axis Acceleration
Z-axis Acceleration	Groundtrack (Degrees)
True Altitude	Throttle Input
Latitude	Longitude
True Heading	Vertical Velocity (Feet per Minute)
True Altitude (Mean Sea Level)	Drop Score (Bearing)
Drop Score (Distance)	Crash Code
Elevator Trim (Degrees)	Throttle Angle
Flap Position (Percent)	Course Deviation (Nautical Miles)
Past Waypoint	Segment Flags

The dependent measures from the eye movement measurements were as follows:

1. Total number of glances at each window and at instruments.
2. Total time spent looking at each window and at instruments.
3. Percent of total time spent looking at each window and at instruments.
4. Percent of glance time for each window and for instruments.
5. Percent of total time per glance.

Note. A glance is defined as the focal point passing through a given window or instrument.

Procedure

Each subject was given a 1/2-hour briefing on the nature of the study and the requirements of the tasks. The requirements included information on optimum flight parameters, flight path, and position checkpoints. Each subject was initialized at a predetermined point and instructed to maintain the specified altitudes, airspeeds, and headings.

Each subject performed two trials per day (one trial for each FOV condition), on 2 consecutive days. After finishing the trials, the pilots completed questionnaires on the research effort and the use of the eye tracker (see Appendices B and C).

A copilot assisted the subjects with navigation and aircraft configuration during the study. The primary duties of the copilot consisted of map reading, point detection, and in-flight checklists. The same copilot was used for all subjects in order to maintain continuity throughout the research effort.

Data Analysis

For analysis purposes, the data were analyzed by mission segment. An initial analysis revealed no order effects; therefore, order was ignored in subsequent analyses. The different low-level legs (1 and 2), turns (right and left), and the airdrop portion comprised the five parts examined. A resident software program called Success (Qualtech Systems, Provo, Utah) was used to define the various break points for the five parts. The time and groundtrack variables were plotted. The plotted information allowed break point determinations based on heading changes. The five data files were analyzed using the SPSS-X Multiple Analysis of Variance (MANOVA) program resident on the AFHRL's VAX 11/780 computer system. In cases where the MANOVA indicated significant results ($p < .05$), further examination of the univariate ANOVAs was performed. These analyses concentrated on the means and standard deviations of the following variables:

Airspeed (KIAS)
Bank Angle (Degrees)
Yaw Rate (Degrees per Second)
Pitch Rate (Degrees per Second)
Y-axis Acceleration
Groundtrack (Degrees)
Drop Score (Bearing)
Normal Acceleration (Gs)
Angle of Attack (Degrees)
Pitch Angle (Degrees)
Roll Rate (Degrees per Second)
X-axis Acceleration
Z-axis Acceleration
Vertical Velocity (Feet per Minute)
Drop Score (Distance)

Data from the eye position camera were encoded using a personal computer applications program (Tapemaster, Comprehensive Video Supply Corporation). The Tapemaster program allowed the researchers to define visual area codes (area within each window, instruments, or other) for the visual field. The separation between each window was used for the determination of the window areas. "Instruments" was defined as eyes transitioning to the instrument area, and "Other" was all actions not related to windows or instruments (e.g., map reading). The definitions for each area were encoded and input to the computer manually. The encoded data were spot-checked by independent researchers to ensure that the visual area codes were properly input, and then transferred to the VAX 11/780 for further analysis. The SPSS-X MANOVA program was used in the same manner as above to determine the results of the data. The data from Windows 3 and 6 (the windows not available in the limited-FOV condition) were not included in the final data analysis. The variables used for analysis included: total time in each window, total glances in each window, percent of total time and glance time for each window, and percent of total time per glance.

IV. RESULTS

Eye Position Data

The eye position data were separated into categories of total time and number of glances per window, average time and glances per window, and percent of total time and glances per window.

There was a multivariate effect for FOV. This effect was concentrated in the percent of total time for Window 2 and percent of total glances for Windows 1 and 2, and Instruments. The variable values and levels of significance are shown in Table 1.

Table 1. **Means of Significant Univariate FOV Effects for Eye Position Variables**

Variable	Full FOV	Limited FOV	F	p
% TIME WINDOW 2	6.7%	5.5%	5.256	.028
% GLANCES WINDOW 1	44.5%	47.7%	8.509	.001
% GLANCES WINDOW 2	12.2%	8.8%	11.418	.002
% GLANCES INSTR	38.3%	41.4%	9.279	.005

No significant FOV by Route interactions were detected for the percent of total time and percent of total glances; however, there was a univariate effect found for Route. This effect was shown in the percent of total time for Window 2. The associated means were .053% for Route 1 and .070% for Route 2 (F = 9.758, p = .004).

There were no FOV effects or FOV by Route interaction effects for the average time per glance per window. However, a significant Route effect was found, as shown by the longer mean glance times in Window 2 on Route 2. The means for Routes 1 and 2 were 1.054 and 1.255 glances per window, respectively (F = 10.356, p = .003).

There were no FOV by Route interaction effects for the eye position data. There was a multivariate effect for Route and FOV, concentrated in total time and glances for Window 2. Tables 2 and 3 depict these variables and their associated values.

Table 2. **Means of Significant Univariate Route Effects for Eye Position Variables**

Variable	Route 1	Route 2	F	p	r^2
TIME WINDOW 2	44.677	62.613	14.250	.001	.12
GLANCES WINDOW 2	42.333	51.708	5.917	.021	.04

Table 3. **Means of Significant Univariate FOV Effects for Eye Position Variables**

Variable	Full FOV	Limited FOV	F	p	r^2
TIME WINDOW 2	58.995	48.295	5.072	.031	.04
GLANCES WINDOW 2	53.000	41.042	9.627	.004	.07

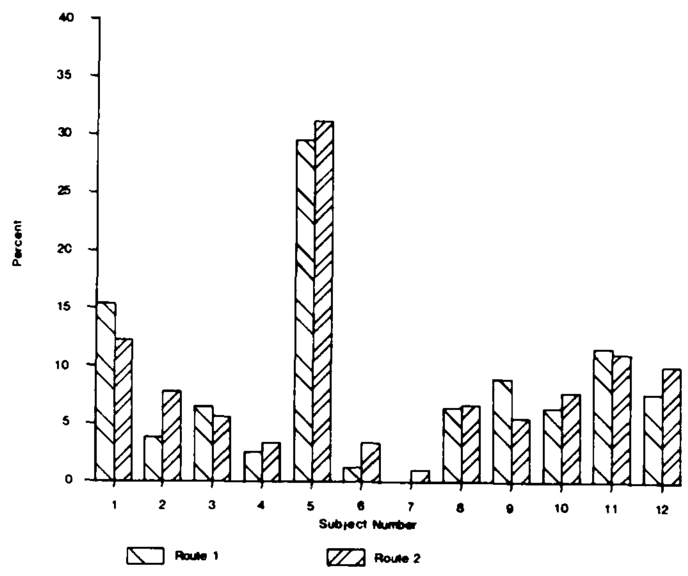

Figure 9. **Percent of Total Glances for Window 3.**

Figure 9 depicts the percent of total glances for Window 3. The figure also demonstrates the range of individual variation. Use of Window 6 is not presented because it was near zero for most subjects. Window 6 is actually functionally equivalent to Window 3 but for copilot position. The mean percentage of total time for Window 3 is 15.8%, with a 11.9% standard deviation.

Simulator Performance Data

The simulator performance data revealed several significant effects for the interaction of FOV by Route, FOV, and Route. The most consistent and significant effects were found between the different routes. These effects are to be expected, simply based on the differences between the two courses flown. The significant univariate effects noted for Route are not of primary interest in this study and are listed in Appendix D only for reference purposes.

The FOV by Route interactions were found in the right and left turn segments of the performance data. For left turns, the effect was revealed in the standard deviation of the airspeed (F = 7.719, p = .010). This interaction is shown in Figure 10. For right turns, the univariate effect was noted for the standard deviation of the groundtrack (F = 6.934, p = .014). Figure 11 displays this interaction.

The only significant univariate effects noted for the FOV were in the first low-level flight segment. These effects were for the mean altitude and mean roll rate (see Table 4).

Table 4. **Means of Significant Univariate FOV Effects for Leg 1 Variables**

Variable	Full FOV	LIMITED FOV	F	p
MEAN ALTITUDE	396.647 FT AGL	435.344FT AGL	4.81	.037
MEAN ROLL RATE	-0.008 D/S	-0.015 D/S	4.208	.050

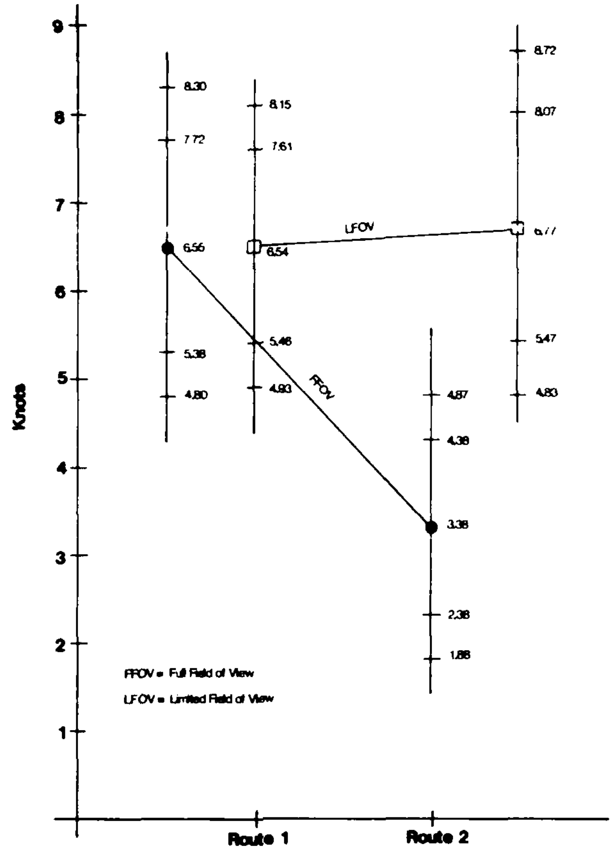

Figure 10. **Field of View by Route Interaction Standard Deviation of Airspeed.**

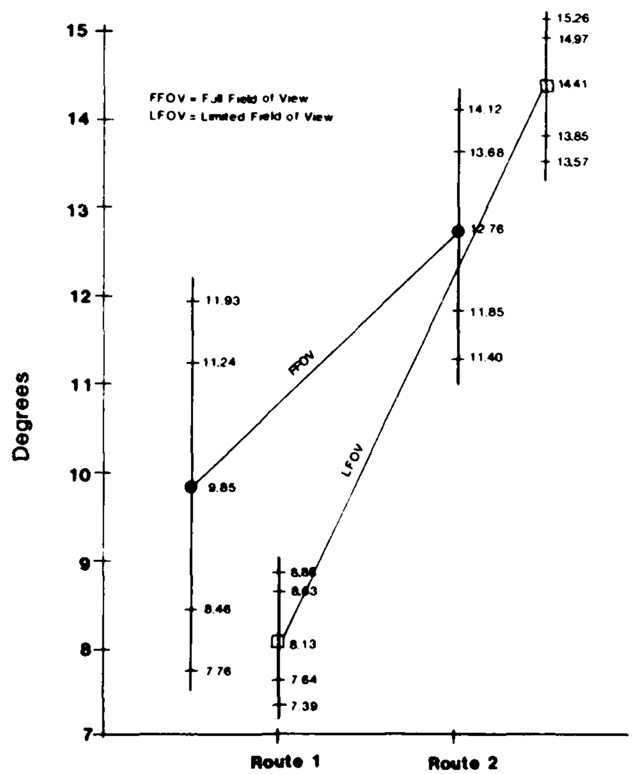

Figure 11. **Field of View by Route Interaction Standard Deviation of Groundtrack.**

Questionnaire Data

C-130 WST Study Questionnaire Summary. All subjects agreed that the tasks used to assess FOV were effective. Subjects also suggested that FOV research be conducted on other tasks such as assault landings, traffic patterns, takeoffs, and tactical recoveries. Eight of the twelve subjects indicated that flight performance was hampered in the limited-FOV condition. Seven of the ten subjects felt that the level of detail in the visual scene should be increased to enhance realism. A summary of all responses to this questionnaire is included in Appendix B.

Eye Camera Questionnaire Summary. Pilot opinion regarding the eye camera apparatus indicated that the device was only slightly uncomfortable. Pilots reported having little reluctance to turn their heads while wearing the device and indicated that it had little effect on their flying performance. They reported very little additional eyestrain due to the device, but felt that it detracted from the realism of the mission somewhat. A summary of all responses to this questionnaire is included in Appendix C.

V. CONCLUSIONS

The purpose of the present investigation was to assess the value of the farthermost peripheral windows on the performance of tasks deemed most likely to require peripheral information. The results indicate that these windows provide useful information and that their absence alters some aspects of pilot performance. However, the effects are neither large nor dramatic. The results also show that pilots quickly adapt to the altered configuration and adopt effective compensating strategies. It is clear that these windows are not "necessary" in the sense that their absence prevents or severely degrades performance. The pilots can do the tasks about equally well whether the windows are on or off.

The pilots who served as subjects in this experiment were highly experienced in the C-130 aircraft and possessed all the prerequisite skills for performing the tasks. Presumably, they performed the task in the full-FOV condition in much the same manner as they would in the aircraft (this is admittedly an unresolved issue). The use of the eye position monitor allowed us to directly assess the visual behavior in both FOV conditions. The data from this source show that the absence of these windows did affect visual performance, in that pilots relied more on their instruments. Relying on instruments is probably not a desirable strategy for this type of task. More importantly, it would not be desirable to have transitioning pilots learn such a strategy in the simulator and transfer this strategy to the aircraft. The acquisition of less-than-optimal scanning habits or potentially interfering habits is perhaps the greatest concern among senior training managers. It is, in fact, this issue which drives the high-fidelity requirements in FOV displays. It would be desirable to know how these tasks should be performed, so that observed behaviors could be compared against the standard. Such information could be obtained by gathering in-flight eye position data. Discussions for such research are currently underway.

The use of the eye position data in FOV research is clearly an advance over relying on ratings or even objective performance data from the system state of the aircraft. Having direct access to the pilot's visual behavior allows for a much more in-depth understanding of the impact of the variable. However, this approach also has its limitations. It reveals only the focal point and does not deal with visual information that is available and processed from the visual periphery. For example, when the pilot is looking at something in Window 2, his visual periphery is also being stimulated by the information in Window 3. Thus, even though the pilots do not look directly at Window 3 as frequently as the other windows, they are often getting peripheral input from this window, especially when the focal point is in Window 2. Optical flow information from the periphery is thought to be an important factor in maintaining orientation. The fact that this input is important is revealed by the decreased use of Window 2 in the limited-FOV condition.

Although two different routes were used in this study primarily as a way to control for familiarization of the task and to force use of the out-of-the-cockpit visual cues, it is instructive to note that there were several significant FOV by Route interactions. This finding indicates that the need for peripheral visual information is more than task-specific in a generic sense; it is likely to be terrain/geographic-by-task-specific.

The general conclusion that can be drawn from this study is that although experienced pilots can perform the tasks without the two most peripheral windows, their performance is slightly altered in the absence of these windows. There are a number of other tasks which currently are not taught or practiced in the C-130 WST that may make use of these windows. By having the windows available, the potential for expanding the syllabus to include these tasks would be possible. However, for many tasks currently taught, these windows could be turned off and the scene content in the remaining windows could be enhanced. A channel of the image generator is dedicated to providing the scene content for these two windows. Thus, if the windows are not needed, additional detail in the scene could be provided to the remaining visual displays. The findings of the Hubbard et al. (1988) study would support such a training device strategy.

VI. RECOMMENDATIONS

Based upon the results of this study and the earlier study (Hubbard et al., 1988), the following recommendations are offered regarding the FOV for the C-130 WST:

1. For experienced C-130 pilots and tasks which do not require significant visual search or are primarily straight-ahead in nature, the scene content of Windows 1, 2, 4, and 5 should be enhanced, rather than using Windows 3 and 6.

2. For transitioning pilots, Windows 3 and 6 should be used for all tasks except those that are straight-ahead flight, until further research is accomplished with this category of pilots.

3. Further research should be conducted in the following areas:

a. Investigating skill acquisition and transfer to the aircraft on selected tasks pretrained in the WST under alternative FOV configurations.

b. Obtaining eye position data from experienced pilots in the WST and the aircraft.

c. Exploring the use of an eye position monitor in the training context.

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APPENDIX B: SUMMARY OF C-130 WST STUDY QUESTIONNAIRE RESPONSES

Please take a moment of your time to aid in the evaluation of the C-130 WST study. Your input is greatly appreciated and will be used to determine the effectiveness of the study.

INSTRUCTIONS: Please answer each question to the best of your ability.

1. Did you feel that the tasks used in the study were useful in evaluating field of view requirements?

RESPONSES: 12 Yes 0 No

2. What additional tasks, if any, would you use in this type of research?

RESPONSES:

Landings/Takeoffs (3/12)
Use of Navigator and Copilot (2/12)
Visual Recoveries (1/12)
Tactical Recoveries (1/12)
Pattern Work (2/12)

3. Was your flight performance hampered by the limited-field-of-view condition?

RESPONSES: 8 Yes 4 No

If "Yes," in what way?

Terrain Clearances
More Instrument Checks
Couldn't See Drop Zone

4. Which tasks should be added to/deleted from the C-130 syllabus?

RESPONSES: None.

5. What changes should be made on the C-130 WST to enhance the value of training?

RESPONSES:

More Realistic
Increase Scene Concentration
Clouds
Improve quality

6. Additional Comments?

RESPONSES: None.

APPENDIX C: SUMMARY OF EYE CAMERA QUESTIONNAIRE RESPONSES

Please take a moment of your time to aid in the evaluation of the eye tracking equipment. Your input is greatly appreciated and will be used to determine the effectiveness of the device in future studies. INSTRUCTIONS: Circle the appropriate number for each question.

1. Did the eye tracking device become uncomfortable at any time?

1	3	5
Not at All	Moderately	A Great Deal

RESPONSES: 2, 4, 2, 2, 3, 2, 4, 2, 3, 2, 1, 3. MEAN = 2.5 STD = 0.86

2. Did you feel reluctant to turn your head during the mission due to the device?

1	3	5
Not at All	Moderately	A Great Deal

RESPONSES: 3, 2, 1, 1, 1, 3, 3, 1, 1, 1, 1, 2. MEAN = 1.667 STD = 0.85

3. Did you feel this device inhibited your flying performance?

1	3	5
Not at All	Moderately	A Great Deal

RESPONSES: 1, 2, 1, 1, 2, 2, 3, 3, 1, 2, 1, 2. MEAN = 1.75 STD = 0.72

4. Did you experience any additional eyestrain due to the device?

1	3	5
Not at All	Moderately	A Great Deal

RESPONSES: 2, 1, 1, 2, 1, 1, 1, 1, 1, 3, 1, 1. MEAN = 1.33 STD = 0.62

5. Did you feel that the device had a significant effect on the realism of the mission?

1	3	5
Not at All	Moderately	A Great Deal

RESPONSES: 2, 1, 1, 1, 5, 2, 3, 2, 1, 2, 4, 1. MEAN = 2.08 STD = 1.25

APPENDIX D: SIGNIFICANT ROUTE EFFECTS FOR PILOT PERFORMANCE MEASURES

Means of Significant Univariate Route Effects for Leg 1 Variables

Variable	Route 1	Route 2	F	p
MEAN ACCELERATION	-1.003	-0.999	20.942	.000
MEAN ROLL	-0.007	-0.017	6.237	.019
MEAN PITCH RATE	0.023	0.002	14.386	.001
MEAN X-AXIS	0.930	0.975	4.318	.047
MEAN Z-AXIS	0.454	0.287	19.528	.000
MEAN GROUNDTRACK	104.783	-101.466	2 X 106	.000

Means of Significant Univariate Route Effects for Turn 1 Variables

Variable	Route 1	Route 2	F	p
MEAN AIRSPEED	203.940	208.865	4.227	.050
SD AIRSPEED	6.549	4.988	5.109	.032
MEAN ALTITUDE	537.135	360.691	27.003	.000
SD ALTITUDE	167.642	100.560	22.138	.000
MEAN VVI	520.415	249.854	8.757	.006
SD VVI	1258.433	741.359	14.571	.001
MEAN AOA	2.136	1.839	4.361	.046
MEAN BANK	-20.138	12.416	305.400	.000
SD BANK	12.445	10.028	7.518	.011
MEAN PITCH	3.201	2.101	12.376	.002
SD PITCH	3.386	2.055	17.676	.000
MEAN YAW	-1.709	1.126	408.405	.000
MEAN ROLL	0.181	-0.045	1.776	.000
MEAN PITCH RATE	0.794	0.425	28.950	.004
MEAN X-AXIS	2.382	1.487	20.029	.000
MEAN Y-AXIS	-0.070	0.725	8.13	.008
MEAN GROUNDTRACK	72.535	-79.628	4147.492	.000
SD GROUNDTRACK	22.043	16.930	17.361	.000

Means of Significant Univariate Route Effects for Leg 2 Variables

Variable	Route 1	Route 2	F	p
MEAN ALTITUDE	467.335	307.144	68.238	.000
SD ALTITUDE	188.997	90.234	210.882	.000
MEAN VVI	-82.700	-119.865	6.020	.021
SD VVI	666.550	538.477	8.816	.006
MEAN AOA	1.483	1.526	5.376	.028
MEAN BANK	-0.258	-0.880	4.965	.034
SD PITCH	1.796	1.480	7.106	.013
MEAN Y-AXIS	0.626	0.177	11.911	.000
MEAN GROUNDTRACK	50.766	-68.412	3 X 104	.000

Means of Significant Univariate Route Effects for Turn 2 Variables

Variable	Route 1	Route 2	F	p
SD AIRSPEED	2.750	3.692	6.891	.014
MEAN ALTITUDE	692.690	457.200	30.128	.000
SD ALTITUDE	152.839	76.541	32.829	.000
MEAN AOA	1.777	1.933	4.562	.042
SD AOA	0.565	0.730	7.522	.111
SD ACL	0.136	0.171	6.675	.016
SD BANK	8.289	10.542	12.961	.001
SD YAW	1.195	1.492	4.211	.050
MEAN ROLL	-0.054	0.115	14.783	.001
SD PITCH RATE	0.892	1.204	8.142	.008
SD X-AXIS	0.550	0.662	6.403	.018
SD Z-AXIS	4.637	5.656	5.529	.026
MEAN GROUNDTRACK	41.285	-88.153	5.8 X 103	.000
SD GROUNDTRACK	8.959	13.546	59.413	.000

APPENDIX D: Concluded

Means of Significant Univariate Route Effects for Leg 3 Variables

Variable	Route 1	Route 2	F	p
MEAN AIRSPEED	168.461	164.528	5.331	.030
MEAN ALTITUDE	429.862	492.435	21.611	.000
SD ALTITUDE	212.196	182.114	5.042	.034
MEAN VVI	-27.834	91.486	131.370	.000
MEAN BANK	-0.737	-0.144	4.805	.038
SD BANK	3.160	3.702	8.921	.006
MEAN PITCH	2.067	2.732	54.487	.000
SD PITCH	2.133	2.663	14.148	.001
SD YAW	0.729	0.865	17.723	.000
MEAN X-AXIS	0.799	1.206	62.156	.000
SD X-AXIS	1.725	1.968	15.964	.001
MEAN Y-AXIS	0.418	0.141	9.578	.005
MEAN GROUNDTRACK	32.009	-102.838	1.6 X 104	.000